

# Soil quality improvement and assessment in relation to conservation agricultural practices

**K.L. Sharma**

**Principal Scientist and National Fellow (ICAR)**

Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad

[klsharma@crida.ernet.in](mailto:klsharma@crida.ernet.in)

## 1. Introduction

Indian sub-continent predominantly represents wide spectrum of climate ranging from arid to semi arid, sub humid and humid with wider variation in rainfall amount and pattern. Seasonal temperature fluctuations are also vast. Soils representing rainfed regions are marginally low in organic matter status. The first predominant cause of soil degradation in rainfed regions undoubtedly is water erosion. The process of erosion sweeps away the topsoil along with organic matter and exposes the subsurface horizons. The second major indirect cause of degradation is loss of organic matter by virtue of temperature mediated fast decomposition of organic matter and robbing away of its fertility. Above all, the several other farming practices such as reckless tillage methods, harvest of every small component of biological produce and virtually no return of any plant residue back to the soil, burning of the existing residue in the field itself for preparation of clean seed bed, open grazing etc aggravate the process of soil degradation.

## 2. Predominant causes of soil degradation

The predominant reasons which degrade soil quality and deteriorate its productive capacity could be enumerated as: i) washing away of topsoil and organic matter associated with clay size fractions due to water erosion resulting in a 'big robbery in soil fertility', ii) intensive deep tillage and inversion tillage with moldboard and disc plough resulting in a) fast decomposition of remnants of crop residues which is catalyzed by high temperature, b) breaking of stable soil aggregates and aggravating the process of oxidation of entrapped organic C and c) disturbance to the habitat of soil micro flora and fauna and loss in microbial diversity, iii) dismally low levels of fertilizer application and widening of removal-use gap in plant nutrients, iv) mining and other commercial activities such as use of top soil for other than agricultural purpose, v) mono cropping without following any suitable rotation, vi) nutrient imbalance caused due to disproportionate use of primary, secondary and micronutrients, vii) no or low use of organic manures such as FYM, compost, vermi-compost and poor recycling of farm based crop residues because of competing demand for animal fodder and domestic fuel, viii) no or low green manuring as it competes with the regular crop for date of sowing and other resources, ix) poor nutrient use efficiency attributing to nutrient losses due to leaching, volatilization and denitrification, x) indiscriminate use of other agricultural inputs such as herbicides, pesticides, fungicides, etc., resulting in poor soil and water quality, xi) water logging, salinity and alkalinity and acid soils. As a result of several above-mentioned reasons, soils encounter diversity of constraints broadly on account of physical, chemical and biological soil health and ultimately end up with poor functional capacity (Sharma et al., 2007).

## 3. Conservation agriculture and its components

Conservation agriculture is a practice that reduces soil erosion, sustains soil fertility, improves water management and reduces production costs, making inputs and services affordable to small-scale farmers. Conservation agriculture is defined as a set of practices aimed at achieving the following three principles simultaneously: i) maintaining adequate soil cover, ii) disturbing the soil minimally, and iii) ensuring crop rotation and intercropping. Conservation agriculture as defined by Food and

Agricultural Organizations (FAO) of the United Nations, is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. It is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt the biological processes (Philip et al., 2007). Conservation agriculture, in broader sense includes all those practices of agriculture, which help in conserving the land and environment while achieving desirably sustainable yield levels. Tillage is one of the important pillars of conservation agriculture which disrupts inter dependent natural cycles of water, carbon and nitrogen. Conservation tillage is a generic term encompassing many different soil management practices. It is generally defined as ‘any tillage system that reduces loss of soil or water relative to conventional tillage; mostly a form of non-inversion tillage allows protective amount of residue mulch on the surface (Mannering and Fenster, 1983). Lal (1989) reported that the tillage system can be labeled as conservation tillage if it i) allows crop residues as surface mulch, ii) is effective in conserving soil and water, iii) maintains good soil structure and organic matter contents, iv) maintains desirably high and economic level of productivity, v) cut short the need for chemical amendments and pesticides, vi) preserves ecological stability and vii) minimizes the pollution of natural waters and environments. In order to ensure the above criteria in agriculture, there is a need to follow a range of cultural practices such as i) using crop residue as mulch, ii) adoption of non-inversions or no-tillage systems, iii) promotion of crop rotations by including cover crops, buffer strips, agroforestry, etc., iv) enhancement of infiltration capacity of soil through rotation with deep rooted perennials and modification of the root zone; v) enhancement in surface roughness of soil without jumping into fine tilth, vi) improvement in biological activity of soil fauna through soil surface management and vii) reducing cropping intensity to conserve soil and water resources and building up of soil fertility.

#### **4. Conservation agriculture vis-à-vis soil quality**

Various research reports have emphasized that conservation agricultural practices play an important role in preventing the soils from further degradation and in restoring back the dynamic attributes of soil quality. According to Doran and Parkin (1994) and Karlen *et al.*, (1997), soil quality is defined as the functional capacity of the soil. Seybold *et al.*, (1998) defined the soil quality as ‘the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality and support human health and habitation.’ Quality with respect to soil can be viewed in two ways: (1) as inherent properties of a soil; and (2) as the dynamic nature of soils as influenced by climate, and human use and management. This view of soil quality requires a reference condition for each kind of soil with which changes in soil condition are compared and is currently the focal point for the term ‘soil quality’. The soil quality as influenced by management practices can be measured quantitatively using physical, chemical and biological properties of soils as these properties interact in a complex way to give a soil its quality or capacity to function. Thus, soil quality cannot be measured directly, but must be inferred from measuring changes in its attributes or attributes of the ecosystem, referred to as ‘indicators’. Soil quality comprises of three predominant indicator groups. These are: i) Soil chemical quality and soil fertility indicators (Soil acidity/salinity- alkalinity, soil organic matter content and essential plant nutrient status etc.) ii) Soil physical quality indicators (Soil texture, structure, bulk density, hydraulic conductivity, porosity etc) and (3) Soil biological quality indicators (microbial activity and soil respiration, soil organic C, soil enzymatic activity etc.).

Hence, while considering soil quality, it is important to give attention to all the three categories of indicators.

### **5. How conservation tillage and residue management help in improving soil properties and ultimately soil quality?**

Conservation tillage and residue management help in the following ways in influencing some of the soil properties.

- **Soil Temperature:** Surface residues significantly affect soil temperature by balancing radiant energy and insulation action. Radiant energy is balanced by reflection, heating of soil and air and evaporation of soil water. Reflection is more from bright residue.
- **Soil aggregation:** It refers to binding together of soil particles into secondary units. Water stable aggregates help in maintaining good infiltration rate, good structure, protection from wind and water erosion. Aggregates binding substances are mineral substances and organic substances. Organic substances are derived from fungi, bacteria, actinomycetes, earthworms and other forms through their feeding and other actions. Plants themselves may directly affect aggregation through exudates from roots, leaves and stems, leachates from weathering and decaying plant materials, canopies and surface residues that protect aggregates against breakdown with raindrop impact, abrasion by wind borne soil and dispersion by flowing water and root action. Aggregates with 0.84 mm in diameter are non-erodable by wind and water action.
- **Soil density and porosity:** Soil bulk density and porosity are inversely related. Tillage layer density is lower in ploughed than unploughed (area in grass, low tillage area etc). When residues are involved, tilled soils will reflect lower density. Mechanization with heavy machinery results in soil compaction, which is undesirable and is associated with increased bulk density and decreased porosity.
- **Effects on other physical properties:** Tillage also influences crusting, hydraulic conductivity and water storage capacity. It has been understood that the textural influences and changes in proportion of sand, silt and clay occur due to inversion and mixing caused by different tillage instruments, tillage depth, mode of operation and effect of soil erosion. Soil crusting which severely affects germination and emergence of seedling is caused due to aggregate dispersion and soil particles resorting and rearrangement during rainstorm followed by drying. Conservation tillage and surface residue help in protecting the dispersion of soil aggregates and helps in increasing saturated hydraulic conductivity.
- **Effect on soil organic matter and soil fertility:** Conservation agricultural practices help in improving soil organic matter by way of i) regular addition of organic wastes and residues, use of green manures, legumes in the rotation, reduced tillage, use of fertilizers, and supplemental irrigation ii) drilling the seed without disturbance to soil and adding fertilizer through drill following chemical weed control and iii) maintaining surface residue, practicing reduced tillage, recycling of residues, inclusion of legumes in crop rotation. These practices provide great opportunity in maintaining and restoring soil quality in terms of SOM and N in SAT regions.

### **6. Evaluation of conservation agricultural practices for soil quality:**

Measurement of the indicators can help in quantifying the soil quality status. Recently, a key indicator concept has been initiated. In order to monitor soil quality using soil quality indices, one has to identify the key indicators of soil quality for a particular soil type. To identify key indicators, one needs to analyze the soil rigorously for various physical, chemical and biological attributes (Sharma et al., 2005). The following major steps are involved during the computation of soil quality: i) fixing or defining the goals, ii) testing the level of significance for various soil indicator

as influenced by various management treatments, iii) select representative minimum data set (MDS) through Principal component analysis (PCA), iv) correlation analysis among soil variables to reduce spurious grouping among highly weighted variables within each PC, v) multiple regression using the final MDS components as the independent variables and each goal attribute as a dependent variables, vi) scoring of the MDS indicators based on their performance of soil function and computation of soil quality index (SQI). The data obtained for all the chemical, physical and biological soil quality indicators need to be tested for their level of significance using statistical analysis. The soil quality evaluation need to be tested against some functional goals viz., long-term average yields of sorghum and mung bean, sustainability yield index (SYI) and organic matter. After testing the level of significance, the data is subjected to principal component analysis to identify the minimum data set (MDS) as suggested earlier by Doran and Parkin (1994) and Andrews *et al.* (2002a) and followed by Sharma *et al.* (2005). After identifying the MDS indicators, every observation of each MDS indicator should be transformed using a linear scoring method as suggested by Andrews *et al.* (2002a). To assign the scores, indicators are arranged in order depending on whether a higher value was considered “good” or “bad” in terms of soil function. In case of ‘more is better’ indicators, each observation was divided by the highest observed value such that the highest observed value received a score of 1. For ‘less is better’ indicators, the lowest observed value (in the numerator) was divided by each observation (in the denominator) such that the lowest observed value received a score of 1. After transformation using linear scoring, the MDS indicators for each observation should be weighted using the PCA results. Each PC explained a certain amount (%) of the variation in the total data set. This percentage when divided by the total percentage of variation explained by all PCs with eigenvectors > 1, gives the weighted factors for indicators chosen under a given PC. After performing these steps, to obtain soil quality index (SQI), the weighted MDS indicator scores for each observation should be summed up using the following relation:

$$SQI = \sum_{i=1} (W_i \times S_i)$$

Where  $S_i$  is the score for the subscripted variable and  $W_i$  is the weighing factor obtained from the PCA. Here the assumption is that higher index scores meant better soil quality or greater performance of soil function.

## 7. Effect of Conservation Management Practices on Soil Quality

There are several reports on the influence of conservation agricultural management practices comprising of tillage, residue recycling, application of organic manures, green manuring and integrated use of organic and inorganic sources of nutrients, soil water conservation treatments, integrated pest management, organic farming, etc., on soil quality. Most of the soil quality assessment studies, do not deal with comprehensive data set comprising of all the physical, chemical and biological indicators. However, the results pertaining to the effect of conservation agricultural practices on soil quality are given below: The basic objective of integrated nutrient use is to reduce the inorganic fertilizer requirement, to restore organic matter in soil, to enhance nutrient use efficiency and to maintain soil quality in terms of physical, chemical and biological properties. Bulky organic manures may not be able to supply adequate amount of nutrients, nevertheless their role becomes important in meeting the above objectives. The results pertaining to several studies on integrated nutrient management are discussed as follows: The studies conducted over a 9 year period in Alfisols at Bangalore with finger millet, revealed that the yields were similar with optimum N, P, K application and with 50% NPK applied through combined use of fertilizers + FYM applied @ 10 t ha<sup>-1</sup>. From the viewpoint of sustainability, this treatment proved quite effective. The effect was positive

(>3 t grain ha<sup>-1</sup>) during eight out of nine years. However, sole application of fertilizer could sustain the effect only during four out of nine years. The beneficial effect of FYM and loppings of *Calotropis procera* at the rate of 15 to 20 t ha<sup>-1</sup> improved the soil physical properties, particularly the moisture storage under rainfed conditions. It also benefited the N mineralization and soil nitrogen regime. Application of FYM @ 20 t ha<sup>-1</sup> every alternate year resulted in 60% build up of soil organic matter over a five year period. The effect of organic amendments on soil physical properties was particularly noticeable when the amendments were incorporated in the sub-surface layer viz. 20-25 cm depth. In addition to yield gains, organic manures have proved useful in correcting the deficiencies of several nutrients also. It has been observed that application of FYM over a 10 year period led to a build up of plant available Zinc (Katyal and Randhawa, 1983). FYM application not only reversed the decline in P status of soil with cropping (Brar and Bhajan Singh, 1984), but a distinct rise in P fertility was also seen. The benefits of use of earthworm castings to prepare compost from the waste materials such as city wastes, rural wastes, kitchen wastes, sewage sludge, and farm wastes have been highlighted by many authors (Lee and Wani, 1988; Kale et al. 1990, Sharma et al., 2008). Application of vermicompost in combination with inorganic fertilizer in 1:1 ratio in terms of N equivalence was found very effective in case of sunflower grown in Alfisol at Hyderabad (Neelaveni, 1998).

Combined use of crop residues and inorganic fertilizer showed better performance than sole application of residue. Use of crop residue in soil poor in nitrogen (Bangalore) showed significant improvement in the fertility status and soil physical properties. Continuous addition of crop residues for five years enhanced maize grain yield by 25%. Organic matter status improved from 0.5% in the control plots to 0.9% in plots treated with maize residue at 4 t ha<sup>-1</sup> year<sup>-1</sup>. In Alfisols at Hyderabad, use of crop residues in pearl millet and cowpea not only enhanced the yields but also made appreciable improvements in stability of soil structure, soil aggregates and hydraulic conductivity. At Akola, crop residue application increased sorghum grain yield by 26% in sorghum + pigeon pea intercropping system. Incorporation of residues increased the yield of upland rice at Ranchi by 41% over a base yield of 4.4 q ha<sup>-1</sup>. Loppings (leaves + twigs) of nitrogen fixing trees such as *Leucaena* and *Glyricidia* on an average contain more than 3 per cent N on dry weight basis. These trees can be grown either on bunds or in one corner of the field to generate phytomass to supply nutrients. Application of the loppings of these trees either alone or in conjunction with inorganic fertilizers gave excellent results in enhancing the yields of crops such as sorghum and sunflower (Rao and Singh, 1988; Sharma et al. 2002; Narkhede et al. 1984; Narkhede and Ghugare, 1987). The conjunctive use of urea and organics (1:1) such as *Leucaena* and *Glyricidia* had significant effect in enhancing the grain yield of sorghum to the extent of 1.69 t ha<sup>-1</sup> and 1.72 t ha<sup>-1</sup>, respectively. This approach indicated that 50% of the fertilizer requirement can be met through the application of green leaves and twigs of these trees (Sharma et al., 2002). Capitalisation of legume effect is one of the important strategies of tapping additional nitrogen through biological N fixation. There are many reports on this aspect (Singh and Das, 1984; Sharma and Das, 1992). The beneficial effect of preceding crops on the succeeding non-legume crops has been studied at many locations. Based on a five year rotation of castor with sorghum + pigeon pea and green gram + pigeon pea in an Alfisol of Hyderabad, it was observed that green gram + pigeon pea intercrop (4:1) can leave a net positive balance of 97 kg ha<sup>-1</sup> total N in soil (Das et al. 1990). Comprehensive study on the contribution of legume crop in cropping systems has been made by Katyal and Das, (1993). The hypothesis on the current transfer of N from legume to non-legume component in the intercropping system does not appear to be supported by recent evidences (Das, 1993; Katyal et al. 1991). The response to applied N in legume-non-legume intercropping system was generally lower than the non-legume sole crop (Singh and Das, 1990). Short duration legumes like cowpea and green gram were found more effective in increasing yields of following crops in a rotation through higher N build up in the soil (Das et al. 1991).

Results of a long-term study conducted on soil quality improvement revealed that the application of gliricidia loppings proved superior to sorghum stover and no residue treatments in maintaining higher SQI values. Further, increasing N levels also helped in maintaining higher SQI. Among the 24 treatments, the SQI ranged from 0.90 to 1.27. The highest SQI was obtained in conventional tillage (CT) + gliricidia loppings (GL) + 90 kg N ha<sup>-1</sup> (CTGLN<sub>90</sub>) (1.27) followed by CTGLN<sub>60</sub> (1.19) and minimum tillage (MT) + sorghum stover (SS) + 90 kg N ha<sup>-1</sup> (MTSSN<sub>90</sub>) (1.18), while the lowest was under minimum tillage + no residue (NR) + 30 kg N ha<sup>-1</sup> (MTNRN<sub>30</sub>) (0.90) followed by MTNRN<sub>0</sub> (0.94), indicating relatively less aggradative effects. The application of 90 kg N ha<sup>-1</sup> under minimum tillage even without applying any residue (MTNRN<sub>90</sub>) proved quite effective in maintaining soil quality index as high as 1.10. The key indicators, which contributed considerably towards SQI, were available N, K, S, microbial biomass carbon (MBC) and hydraulic conductivity (HC). On average, the order of relative contribution of these indicators towards SQI was: available N (32 %), MBC (31 %), available K (17 %), HC (16%), and S (4 %). Among the various treatments, CTGLN<sub>90</sub> not only had the highest SQI, but was most promising from the viewpoint of sustainability, maintaining higher average yield levels under sorghum-castor rotation. From the view point of SYI, CT approach remained superior to MT. To maintain yield as well as soil quality in Alfisols, primary tillage along with organic residue and nitrogen application are needed (Sharma et al, 2005).

Another long-term experiment was conducted with two tillage (conventional (CT) and reduced (RT)) and five INM treatments (control, 40 kg N through urea, 4 t compost + 20 kg N, 2 t Gliricidia loppings + 20 kg N and 4 t compost + 2 t Gliricidia loppings) using sorghum and green gram as test crops. It was found that, the order of performance of the treatments in increasing the sorghum yield was 2 Mg gliricidia loppings + 20 kg N through urea (T4) (93.2%) > 4 Mg compost + 20 kg N through urea (T3) (88.7%) > 40 kg N through urea (T2) (88.5%) > 4 Mg compost + 2 Mg gliricidia loppings (T5) (82.2%). In case of mung bean, where half as much nitrogen was applied as was to the sorghum, the order of performance of the treatments in increasing the grain yields was: T3 (63.6%) > T5 (60.3%) > T4 (58.0%) > T2 (49.6%). Tillage significantly influenced the hydraulic conductivity only, whereas, the conjunctive nutrient use treatments significantly influenced the predominant physical, chemical and biological soil quality parameters. Among the conjunctive nutrient use treatments, T5 was found to be superior in influencing the majority of the soil quality parameters and increased the organic carbon by 21.6%, available nitrogen by 24.5%, dehydrogenase activity (DHA) by 56.1%, microbial biomass carbon (MBC) by 38.8 %, labile carbon (LC) by 20.3% and microbial biomass nitrogen (MBN) by 38.8% over the unamended control and proved superior most in improving soil quality. Of the 21 soil quality parameters considered for study, we found that easily oxidizable N (KMnO<sub>4</sub> oxidizable -N) DTPA extractable zinc (Zn) and copper (Cu), microbial biomass carbon (MBC), mean weight diameter (MWD) of soil aggregates and hydraulic conductivity (HC) played a major role in influencing the soil quality and were designated as the key indicators of 'soil quality' for SAT Alfisol under sorghum-mung bean system. Statistically, the overall superiority of the treatments in aggrading the soil quality was: 4 Mg compost + 2 Mg gliricidia loppings (T5) > 2 Mg Gliricidia loppings + 20 kg N through urea (T4) = 4 Mg compost + 20 kg N through urea (T3) > 40 kg N through urea (T2). The extent of percent contribution of the key indicators towards soil quality index (SQI) was: microbial biomass carbon (MBC) (28.5%), available nitrogen (28.6%), DTPA- Zn (25.3%), DTPA- Cu (8.6%), HC (6.1%) and MWD (2.9%) (Sharma et al., 2008).

Based on the network tillage experiment being carried out since 1999 at various centers of All India Coordinated Research Project on Dryland Agriculture (AICRPDA), it was observed that in arid (<

500 mm rainfall) region, low tillage was almost comparable to conventional tillage and the weed management was not so difficult, whereas, in semi arid (500 –1000 mm) region, conventional tillage was found superior.

### **8. Steps to promote conservation farming**

The following steps are needed to promote conservation farming in the future:

1. There is a need to create awareness among the communities about the importance of soil resources, organic matter build up in soil. Traditional practices such as burning of residues, clean cultivation, intensive tillage and pulverization of soil upto finest tilth need to be discouraged.
2. Systems approach is essential for fitting conservation tillage in modern agriculture. In order to follow the principle of “grain is to man and residues is to soil”, farming systems approach introducing alternative fodder crops is essential. Agroforestry systems with special emphasis on silvipastures systems need to be introduced. Unproductive livestock herds needs to be discouraged
3. For the adoption of conservation tillage, it is essential that complete package of practices may be identified based on intensive research for each agro ecological region.
4. The increased use of herbicides has become inevitable for adopting conservation tillage/conservation farming practices. The countries that use relatively higher amount of herbicides are already facing problem of non-point source pollution and environmental hazard. In order to reduce the herbicidal demand, there are scopes to study the allelopathic effects of cover crops and intercultural and biological method of weed control.
5. Low tillage, crop rotation, cover crops, maintenance of residues on the surface, control of weeds through herbicides, are the key components of conservation farming. Therefore, it is essential that these themes must be studied in depth under diverse soil and climatic conditions across the country on long-term basis.
6. The other objective of conservation farming is to minimize the inputs originating from non-renewable energy sources. Eg. Fertilizers and pesticides. Hence, research focus is required on enhancing fertilizer use efficiency and reduction in use of pesticides. This aspect can be strengthened by following integrated nutrient management and integrated pest management approach.
7. The past research experiences of conservation tillage reveal that the major toll of yield is taken by poor germination and poor crop stand because of poor microclimatic environment and hard setting tendencies of soil, excessive weed growth and less infiltration of water to the crop root zone. Therefore, the important aspects which need concentrated research focus include appropriate time of sowing, suitable seed rate, depth of seed placement and soil contact, row orientation, etc. Suitable cultivars having responsiveness to inputs also become important component of conservation farming.
8. The issues related to development of eco-friendly practices for tillage and residue recycling – appropriately for specific combination of soil-agro climatic cropping system – to alleviate physical constraints with higher water and nutrient use efficiency need to be addressed.
9. Inter-disciplinary research efforts are required to develop appropriate implements for seeding in zero tillage, residue incorporation and inter-cultural operations.
10. Research and management strategies to improve soil quality embedding conservation agricultural principles

The following research, developmental and policy strategies are suggested to restore and maintain soil quality on long-term basis by employing the principles of conservation agriculture.

- **Checking soil resource through effective soil and water conservation (SWC) measures:** It is well-accepted connotation that 'Prevention is better than cure'. In order to protect the topsoil, organic matter content contained in it and associated essential nutrients, it is of prime importance that there should be no migration of soil and water out of a given field. If this is controlled, the biggest robbery of clay-organic matter-nutrients is checked. This can be easily achieved, if the existing technology on soil and water conservation is appropriately applied on an extensive scale.
- **Rejuvenation and reorientation of soil testing program in the country:** About more than 600 Soil testing labs situated in the country need to be reoriented, restructured and need to be given fresh mandate of assessing the soil quality in its totality including chemical, physical, biological soil quality indicators and water quality. The testing needs to be on intensive scale and recommendations are required to be made on individual farm history basis. Special focus is required on site-specific nutrient management (SSNM). Soil Health Card system needs to be introduced.
- **Promotion of management practices which enhance soil organic matter:** Management practices such as application of organic manures (composts, FYM, vermi-composts), legume-crop based green manuring, tree-leaf green manuring, residue recycling, sheep-goat penning, organic farming, conservation tillage, inclusion of legumes in crop rotation need to be encouraged (Sharma et al., 2002, 2004).
- **Development and promotion of other bio-resources for enhancing microbial diversity and ensuring their availability:** In addition to organic manures, there is a huge potential to develop and promote bio-fertilizers and bio-pesticides in large scale. These can play an important role in enhancement of soil fertility and soil biological health.
- **Ensuring availability of balanced multi-nutrient fertilizers:** Fertilizer companies need to produce multi-nutrient fertilizers containing nutrients in a balanced proportion in a customized manner so that illiterate farmers can use these fertilizers without much hassle.
- **Enhancing the input use efficiency through precision farming:** The present level of use efficiency of fertilizer nutrients, chemicals, water and other inputs is not very satisfactory. Hence, costly inputs go waste to a greater extent and result in monetary loss and environmental (soil and water) pollution. More focus is required to improve input use efficiency.
- **Amelioration of problematic soils using suitable amendments and improving their quality to a desired level:** History has a record that poor soil quality or degraded soils have taken toll of even great civilizations. No country can afford to let its soils be remaining degraded by virtue of water logging, salinization, alkalinity, erosion etc
- **Land cover management:** Promotion of land cover management is must to protect the soil and to enhance organic matter in soil.
- **Mass awareness about the importance of soil resource and its maintenance:** There is a need to introduce the importance of soil resource and its care in the textbooks at school and college levels. The subject is dealt at present apparently along with geography. Farming communities too need to be made aware about soil, its erosion, degradation, benefits and losses occurred due to poor soil quality.
- **Need to constitute a high power body such as National Authority on Land and Soil Resource Health or National Commission on Soil Resource Health:** State Soil and Water Conservation Departments restrict their activities only up to construction of small check dams, plugging of gullies etc in common lands. State Soil testing labs are almost sluggish in action, poorly equipped and are with under-qualified manpower. Mostly, no tests are done



except for Organic C, P and K. State agricultural universities (SAU) only adopt few villages, and consequently, no extensive testing of soil health is done. ICAR institutions also take up few watersheds. Then, there will be no one to work for Soil Health Care program at extensive scale. Hence, a Central High Power Authority/Commission on soil Resource Health is needed to coordinate the program with States.

## References:

- Andrews SS, Mitchell JP, Mancinelli R, Larlen DL, Hartz TK, Horwarth WR, Pettygrove GS, Scow KM, Munk DS (2002a) On farm assessment of soil quality in California's Central Valley. *Agronomy Journal* 94, 12-23.
- Brar, S.P.S., and Bhajan Singh. 1984. Effect of long-term application of N, P, K and Zn on crop and soil in maize-wheat rotation. *J. Res. Punjab Agric. Univ.*, 21: 349-360.
- Doran, J.W., and Parkin, T. B. 1994. Defining and assessing soil quality. In: *Defining Soil Quality for a Sustainable Environment*. J. W. Doran, D. C. Coleman, D. F. Bezdicek, and B. A. Stewart (Eds.). Soil Sci. Soc. Am. Special Publication No. 35, Madison, Wisconsin, USA, pp. 3-21.
- Das, S.K. 1993. Recent Advances in Dryland Agriculture (Somani et al., Eds.) Scientific Publishers, Jodhpur, 329-341.
- Das, S. K., Rao, A.C.S. and Sharma, K. L (1991). Legume based crop rotation on a dryland Alfisol. *Indian J. Dryland Agric. Res. and Dev.* 6 (1 and 2) : 46-59.
- Das, S. K., Sharma, K. L. and Rao, K.P.C. (1990). Response of castor bean (*Ricinus communis*) to fertilizer nitrogen under different crop rotation on dryland Alfisol. Accepted for XIV International Soil Science Congress held at Tokyo, Japan, August 1990.
- Kale, R. D., Mallesh, B. C., Bano, K. and Bhagyaraj, D. J. 1990. Influence of vermicompost application on the available macronutrients and selected microbial populations in a paddy field. Paper presented at IV Symposium on Earthworms, Arignon, France. June.
- Karlen, D.L., Mausbach, M.J., Doran, J. W., Cline, R. G., Harres, R. F., and Schuman, G. E. 1997. Soil quality: A concept definition, and framework for evaluation. *Soil Sci. Soc. Am. J.* 61: 4-10.
- Katyal J C and Das, S. K. 1993. Fertilizer management in food crops (H.L.S. Tandon Ed). Fertilizer Development and Consultation Organization, pp 61-78
- Katyal J C and Randhawa N S. 1983. Micronutrients (molybdenum). *FAO Fert. Plant Nutr. Bull.* 7: 69-76.
- Katyal, J.C., Das, S.K., Sharma, K. L. and Neelam Saharan. (1991). Effective nutrient management in improving productivity of dryland crops. Proceeding F.A.I. Seminar held on 5-7, December 1991, New Delhi, SVI/1-1-SVII-12.
- Lal, R. 1989. Conservation tillage for sustainable agriculture: tropics versus temperate environments. *Adv. Agro.* 42: 86-197.
- Lee, K. K. and Wani, S. P. 1988. Significance of biological nitrogen fixation and organic manures on soil fertility management. "Soil Fertility and Fertilizer Management in Semi-arid Tropical India". C. Bruce Christianson Ed. Proceedings of Colloquium held at ICRISAT Centres, Patancheru, India from Oct 10-11, 1988, IFDC, 89-108.
- Mannering, J.V., and Fenster, C.R. (1983). What is conservation tillage? *J. Soil Water Conserv.* 38, 141-143.
- Narkhede, P. L. and R. V. Ghugare (1987). Organic recycling in drylands: II: Organic recycling of Subabul on yield, nutrient uptake and moisture utilization by winter sorghum". *J. Ind. Soc. Soil Sci.* 35, 417-420. .

- Narkhede, P. L. Umrani, N. K. and Ghugare, R. V. 1984. "Organic recycling of Subabul for winter sorghum cultivated on drylands. *Indian J Agric. Sci.* 54: 444-446.
- Neeleveni, 1998. Efficient use of organic matter in semi-arid environment through vermiculture composting and management. PhD Thesis submitted to ANGRAU, Rajendranagar, Hyderabad.
- Philip, B., Addo, D. B., Delali, D.G., Asare, B. E., Bernard, T., Soren, D.L., and John, A. 2007. Conservation agriculture as practiced in Ghana. Nairobi: African Conservation Tillage Network; Paris, France; Centre de cooperation international de recherche agronomique, pour le developpement ; Rome, Italy: Food and Agriculture, Organization of the United Nations. p 45.
- Rao, U.M.B., and Singh, S. P. 1988. Crop response to organic sources of nutrients in dryland conditions. National Symp. on Recent Advances in Dryland agriculture, CRIDA, Hyderabad, September, 13-16.
- Seybold CA, Mausbach MJ, Karlen DL, Rogers HH. 1998 Quantification of soil quality. In Lal R, Kimble JM, Follett RF, Stewart BA, eds. *Soil Processes and the Carbon Cycle*. Boca Raton, FL: CRC Press LLC, pp. 387-404.
- Sharma, K. L. Srinivas, K., Das, S. K., Vittal, K. P. R. and Kusuma Grace, J. (2002). Conjunctive Use Of Inorganic and Organic Sources of Nitrogen for Higher Yield of Sorghum in Dryland Alfisol. *Indian Journal of Dryland Agric. Res. & Dev.* 17 (2). 79-88.
- Sharma, K. L. and Das, S. K. (1992). Nitrogen and phosphorus management in dryland crops and cropping systems. In *Dryland Agriculture in India - State of Art of Research in India* (L.L. Somani., K.P.R. Vittal and B.Venkateswarlu eds). Scientific Publishers, P.O. Box 91, Jodhpur -342001, India pp 305-350.
- Sharma, K. L., Vittal, K. P. R., Ramakrishna, Y. S., Srinivas, K., Venkateswarlu, B., and Kusuma Grace, J. 2007. Fertilizer use constraints and management in rainfed areas with special emphasis on nitrogen use efficiency. In: (Y. P. Abrol, N. Raghuram and M. S. Sachdev (Eds)), *Agricultural Nitrogen Use and Its Environmental Implications*. I. K. International Publishing House, Pvt., Ltd. New Delhi. Pp 121-138.
- Sharma, K.L. Kusuma Grace, J. Uttam Kumar Mandal, Pravin N. Gajbhiye, Srinivas, K. Korwar, G. R. Ramesh, V., Kausalya Ramachandran, and S. K. Yadav (2008) Evaluation of long-term soil management practices through key indicators and soil quality indices using principal component analysis and linear scoring technique in rainfed Alfisols. *Australian Journal of Soil Research*. 46: 368-377.
- Sharma, K.L., Mandal, U.K., Srinivas, K., Vittal, K.P.R., Biswapati Mandal, Grace, J.K., and Ramesh, V. 2005. Long-term soil management effects on crop yields and soil quality in a dryland Alfisol. *Soil-and-Tillage-Research*. 83(2): 246-259.
- Sharma, K.L., Srinivas, K., Mandal, U.K., Vittal, K.P.R., Kusuma Grace, J., and Maruthi Sankar, G. 2004. Integrated Nutrient Management Strategies for Sorghum and Green gram in Semi arid Tropical Alfisols. *Indian J. Dryland Agric. Res. Dev.* 19 (1), 13-23.
- Singh R P and Das S K. 1984. Nitrogen management in cropping systems with particular reference to rainfed lands of India. In: *Nutrient management in drylands with special reference to cropping systems and semi-arid red soils*. All India Coordinated Research Project for Dryland Agriculture, Hyderabad, India. pp. 1-56.
- Singh, RP and Das, SK 1990.. "Nutrient management in drylands." *Soil Fertility and Fertiliser Use*. Vol. IV (Ed. V. Kumar et al.). IFFCO, New Delhi, pp. 207-219.